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AN AUTOMATIC GRAPHICAL PROCEDURE FOR RAPID EVALUATION OF INTERLABORATORY STUDIES

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AN AUTOMATIC GRAPHICAL PROCEDURE FOR RAPID EVALUATION OF INTERLABORATORY STUDIES

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DISCLAIMER

The mention of trade names or commercial products in this report does not constitute recommendation and/or endorsement of these products by the Ontario Ministry of the Environment.

ABSTRACT

With the increased use of analytical data from multiple sources, the contributing laboratories are encouraged to participate in as many interlaboratory studies as possible to ensure data quality and comparability. It becomes necessary to develop techniques that will minimize the analytical workload and yet provide a comprehensive, rapid evaluation. Also, the evaluation protocol should present the study findings in a form that is easily understood by all participants.

The graphical procedure described in this report requires only two samples to be analyzed by each participant. It is automated. The graphical presentations enable each participant to 'visualize' their performance. The method is also able to distinguish between different types of errors and identify possible cause(s) of error(s) seen in laboratories not performing satisfactorily.

This report also identifies possible remedial action for the different types of errors.

The historical background and the theory are discussed in section 2. The various trigonometric calculations are described in section 3. Operational instructions, listing and explanations of the computer programs are detailed in section 4.

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1. INTRODUCTION

Interlaboratory studies play an increasingly important role in data quality assessment. Many projects today by their sheer size and extent use data from multiple sources. In such cases, data comparability becomes an important issue to scientists, engineers and other analytical data users. Interlaboratory studies are often used not only to evaluate individual laboratory performance, but also to assess the quality of the database as a whole.

Any valuable interlaboratory study must include as many laboratories as possible. A study that involves minimum laboratory analytical work will encourage more participants. Other attractive features of any study are simplicity of the study protocol, timely release of study findings, and presentation of results in an easily understandable format.

Study evaluations should identify the presence of determinate error(s) observed in a laboratory's data and suggest possible causes and solutions. This will prompt the laboratory to take immediate remedial action. In other words, an effective interlaboratory study must lead to an appropriate action whenever warranted.

The above issues were the main consideration in developing the procedure that is described in this document.

The classical Youden's two-sample graphical procedure for evaluation of interlaboratory data[1] was the starting point of this development. King's extension[2] provided the means of diagnosis and assignment of possible causes of errors. The King - Selliah procedure (K-S procedure) is essentially an effective combination of the above two approaches, automated to meet the goals specified earlier.

The K-S procedure allows the laboratories to be evaluated with respect to either targets (designed values) or consensus values. The graphs enable each participant to visualize their performance. The tabular 'output' suggests the type of error whenever a laboratory is flagged as not performing satisfactorily. The evaluation is fully automated allowing timely release of study findings.

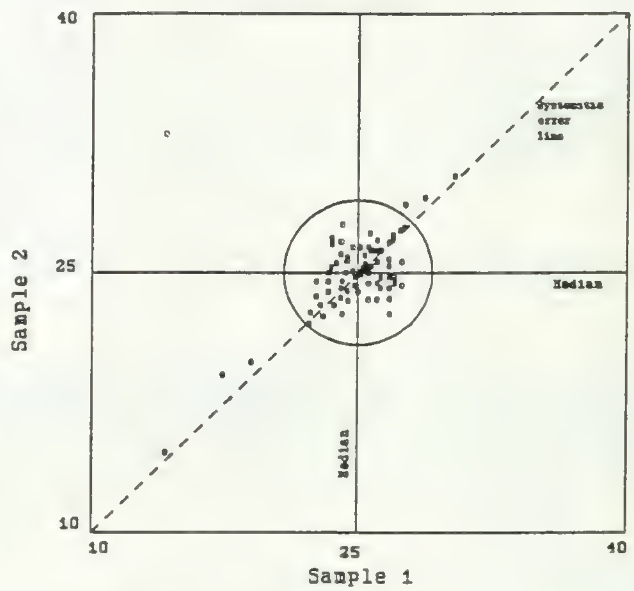
2. THEORY AND DISCUSSION

Many procedures have been developed to evaluate interlaboratory data. Among these, Youden's graphical procedure[1] is by far the simplest. It requires each participant to perform a single analysis on each of two samples of similar concentrations. The graphical evaluation 'output' enables each laboratory to visualize their performance in relation to the rest of the participants and take remedial action if warranted. Extensive statistical knowledge and computation is not required to estimate bias and imprecision.

In the Youden graphical procedure the result of one sample is plotted against the result of the other sample. This presentation distinguishes between random and systematic errors affecting the results. The graph is divided into four quadrants by two lines representing the median value (or the target if known) of each sample (Figure 2.1). In the absence of any systematic errors the results will spread randomly between the four quadrants. However in actual practice the majority of the results are located in the lower left and upper right quadrants. In fact they spread out in a characteristic pattern along the 45 degree line (which only passes through the origin if the samples are exactly equal).

FIGURE 2.1

YOUDEN PLOT



The distance between the point of intersection of the two median (or target) lines and the mark representing the laboratory result is a measure of the total error of the results. The distance from the centre along the 45 degree line gives the magnitude of the systematic error and distance perpendicular to the 45° line is a measure of the random component of the error (repeatability).

It is customary to draw a circle with its centre coinciding with the point of intersection of the two median (or target) lines and a radius of some factor of appropriate standard deviation. The standard deviation itself is derived from the perpendicular distances. Depending on the factor chosen, the circle will represent acceptable repeatability. Laboratories that show a definite bias will tend to distribute along the 45 degree line (see Figure 2.1) outside this circle.

While this approach is useful in identifying laboratories that have problems and in distinguishing the random and systematic component of the total error, it does not provide information as to the type of the systematic error. Biases in analytical measurements may be induced by errors in setting the calibration intercept or slope, or by under-recovery due to method inadequacies. Therefore any systematic errors revealed in the Youden pattern, may or may not be concentration dependant.

An extended version of the Youden plots has been used in the Ontario Ministry of the Environment Laboratories (MOE) for the last 20 years to evaluate between-run control data[2]. Unlike Youden's approach, in this procedure the sample concentrations are dissimilar. This leads to identification of two bias lines. One passes through the origin and indicates bias that is concentration dependant. The other is at 45 degrees if the diagram is scaled properly and indicates bias that is concentration independent.

A similar approach has been used to evaluate a number of recent MOE initiated interlaboratory studies[3,4,5]. Using of two samples of different concentration provided the ability to differentiate between the two kinds systematic errors mentioned earlier.

The K-S procedure being described here for interlaboratory data evaluation, while maintaining the simplicity of the Youden's method provides much more useful information. It is based on an automated spreadsheet 'macro' and includes screening of data for extreme results (outliers), estimating the variability among laboratories for each sample, plotting data points on a X-Y chart, estimating average repeatability, setting up acceptance criteria, and interpreting results. The steps involved in this procedure are outlined at the end of this section (page 10). Each of the major components of this method is described in more detail below.

Data Screening And Estimation of Between-Laboratory Variability

Since most interlaboratory data will include erratic and biased data points, it is necessary to screen the data before evaluating dependence of the precision on concentration. Inclusion of these data in the estimation of standard deviations will exaggerate the variability and will mask useful conclusions that otherwise may be drawn.

The screening process starts with the assumption that the confidence interval for the higher concentration sample will often be about 10%. The standard deviation S_H is calculated using only data which falls within this range of the sample median. The calculation of S_H is reiterated several times to re-include all points which fall within 3x the current estimate of S_H. (If the precision of the data were significantly tighter a smaller initial limit eg. 5% would be used).

The relative standard deviation of the high sample CV_H (S_H/$Mean_{high}$) is then used to obtain the initial estimate of the standard deviation S_L of the lower concentration sample (CV_H *$Mean_{low}$). The data is again evaluated iteratively as in the case of higher concentration sample to obtain the final estimate of S_L .

The above two iterative processes represent an initial attempt to estimate the general dependence of standard deviation on concentration.

When two samples of significantly different concentrations are used, two scenarios can occur. In the first case the variability of the higher concentration sample (S_H) is not significantly different from that of the other (S_L) indicated by the ratio of individual standard deviations (S_H/S_L) being less than two. This implies that the random error of most laboratories is limited by blank or sample preparation variability.

The other situation occurs when the variability of the higher concentration sample (S_H) is significantly higher than that of the lower concentration sample (S_L) as shown by the ratio of S_H/S_L being greater than two. This indicates that random variability may be concentration dependant.

The evaluation procedures for these two cases differ slightly. When the variability is not dependant on concentration, the average repeatability (S_w) is expressed in concentration units and the absolute results (in concentration units) are plotted in the K-S plots. When the variability is dependant on concentration the average repeatability (S_w) is expressed in percent (i.e. actual result x 100 /median (or target)) and results are plotted on a relative scale (percentage recovery) in the graph.

Plotting Data on a X-Y Chart

In either case the result of one sample of each laboratory is plotted against the result of the other sample on a X-Y chart. This leads to a Youden type scatter plot. In a typical graph, in addition to the two median (or target) lines, there are two other lines that bisect the graph representing the slope (concentration) dependant error and the intercept (blank) dependant error. The slope error line passes through the origin and the point of intersection of the two median (or target) lines. The exact position of the intercept error line will depend on the ratio of the median (or target) concentrations of the two samples. Positioning the intercept error line will be discussed in section 3 (trigonometric computation).

Average Repeatability (S_w) Estimation

The process of estimating average repeatability (S_w) is outlined in the step-wise summary at the end of this section (page 10, 5.iii to 5.vi). Estimation of S_w involves trigonometric computation of perpendicular distances (PD) from every data point in the graph to both bias lines (section 3), calculation of an initial estimate of repeatability $S_{w\text{-}init}$ (of all PDs to the 45 degree line) and selection of appropriate PDs for the final estimation of repeatability (S_w).

If a laboratory is considered biased based on $S_{w\text{-}init}$ then the lesser of the two PDs is selected. Other-wise PD to the 45 degree line is selected. The selected PDs are screened for extreme values (values greater than 3 x $S_{w\text{-}init}$ are eliminated from the selection). The final estimate of S_w is obtained by multiplying the average of all those PDs finally selected, by the Youden factor of 1.2533[1].

Acceptance Criteria

The warning limits and control limits for repeatability are set at $2S_w$ and $3S_w$ respectively, representing approximately 95% and 99% confidence intervals.

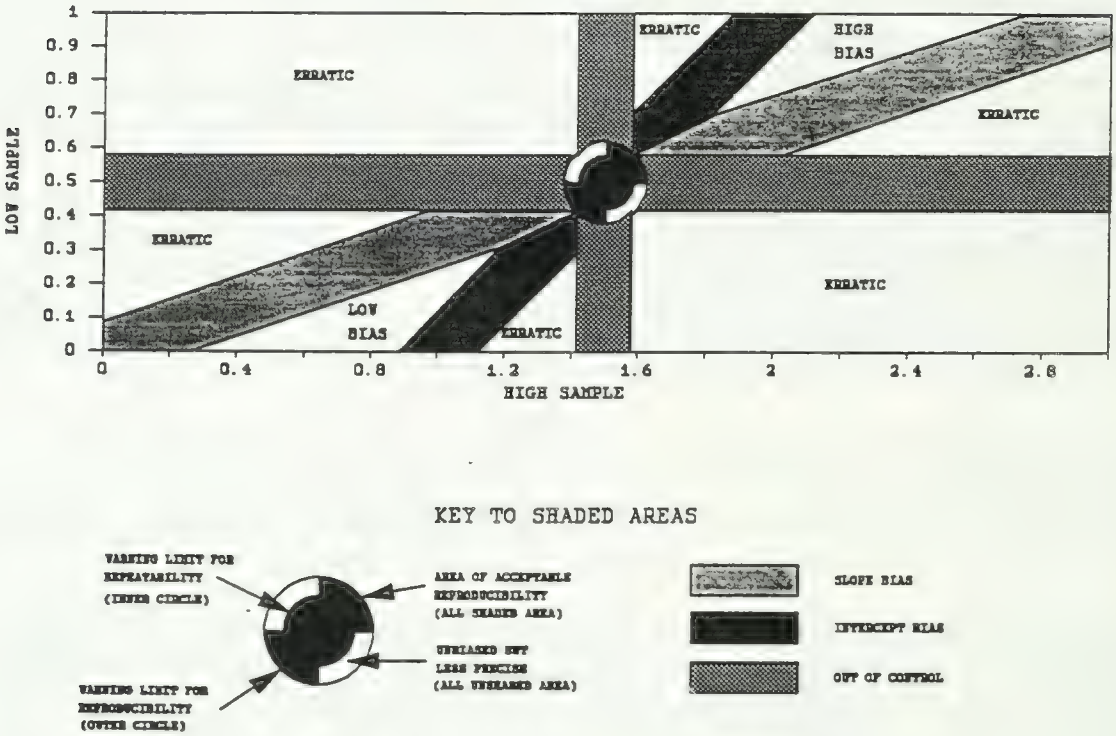
Additional tolerance is required for the effect of variability in preparing and using standards on a day to day or among laboratory basis. The factor 1.5 for the ratio of acceptable reproducibility(S_r) versus repeatability(S_w) was chosen to provide a goal for interlaboratory reproducibility. A ratio $(S_r/S_w)^2$ exceeding 2.3 (i.e 1.5^2) would be considered significant with a risk of error of less than 10%, 5%, and 1% respectively for 10, 20, and 35 degrees of freedom. Results that exceed warning and control limits determined from this desired maximum interlaboratory reproducibility(S_r) are deemed to be possibly or probably biased respectively. Since the reproducibility(S_r) is 1.5 times the repeatability S_w the warning and control limits for bias are set at $3S_w$ and $4.5S_w$ respectively.

Interpretation of Results

The assessment of a laboratory in this type of evaluation is based on the location of its result on the graph. The Figure 2.2 identifies the various regions in a typical graph associated with the different types of problems that might be experienced by the participants in a typical study involving two samples of different concentrations.

Laboratories with controlled repeatability but showing various degrees of bias will appear in the lower left and upper right quadrants. The two circles drawn in these diagram represent the warning limits for repeatability(S_w) and reproducibility(S_r). Those points within the outer circle but in the upper left and lower right quadrants (unshaded in Figure 2) are unbiased but somewhat less precise. Those points within the circle but in the upper right and lower left quadrants are precise and acceptably biased.

FIGURE 2.2



Thus the area of acceptable performance in this diagram has taken the shape of a keyhole. All laboratories that lie outside this area have exceeded the respective warning limits. The term 'acceptable' throughout this discussion is based on the observed performance of those participants reporting comparable data.

Laboratories that lie close to any of the two median (or target) lines (within $2S_w$) have one result correct and the other 'in error'. They are <u>out of control</u>. Laboratories that lie along the intercept error line show <u>intercept dependant bias.</u> Laboratories that lie close to the slope error line show <u>concentration dependant bias</u>. The proximity of a point to any of the above lines will determine the probability of an error corresponding to that type of line. For example if a laboratory lies within $1S_w$ of the intercept error line it is highly probable that this laboratory has blank or intercept related bias. If the laboratory is between $1\text{-}2S_w$ from the intercept line, a blank problem is suspected.

When a laboratory lies between an error line and the adjacent median (or target) line and not close to any of the above, it can be concluded that this laboratory is highly imprecise and biased (<u>biased/erratic</u>).

When a point is between the two error lines but not close to any of these lines it is not possible to identify the type of bias except to document as 'high' or 'low' bias. Laboratories that lie in the upper left or lower right quadrant and are outside the control limits for repeatability ($3S_w$) are very imprecise. The performance of such laboratories is considered erratic

Summary

The K-S procedure while maintaining the simplicity of Youden's method provides much more useful information. It is able to differentiate between two main types of systematic errors.

It is fast and amenable to automation.

The screening of data to exclude erroneous data prevents overestimating the average repeatability achievable in a particular analysis and/or matrices. This information will be very useful for project quality planners and management.

In a recent interlaboratory study[4] the majority of the laboratories that were flagged exhibited slope (concentration) dependant error. In such a case use of certified reference standards to validate the 'in-house' standards or use of the same source of 'quality' external standard will probably improve the data comparability.

In another study[3] (phenolics) many participants displayed blank or baseline related bias. A better control mechanism for determining and correcting or eliminating such effects would be beneficial.

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Sequential Outline of The K-S Procedure

1. Distribute two samples of different concentrations among a number of laboratories for analysis/measurement using their current methodology.

2. Enter data on LOTUS 123® spreadsheet.
   Calculate median (L_m,H_m), means and standard deviations for each sample.
   Tabulate data and return to participating laboratory analyst for verification.
   Correct database if transcriptional errors were reported.

3. Evaluate high sample data:

   i) reject all results which differ from the median (H_m) by more than 10%
   ii) calculate median (H), mean and standard deviation (S_h)
   iii) re-include data if within 3 times S_h
   iv) reiterate ii) and iii) until no further data is included
   v) calculate relative standard deviation of the final selected data (CV_h)

4. Evaluate low sample data:

   i) use 3 x CV_h x (L_m) to exclude possible outliers
   ii) calculate median (L), mean and standard deviation (S_l)
   iii) reinclude data if within 3 times S_l)
   iv) reiterate ii) and iii) until no further data is included.

5. Determine paired sample performance criteria:

   i) examine the ratio of S_h/S_l and if:
   <2 use data as reported in <u>concentration</u> units
   otherwise convert to <u>% recovery</u> based on expected value if known (otherwise use median values (H,L))
   ii) prepare paired sample scatter diagrams of all data
   iii) calculate perpendicular distance from each point to the two error lines (PD_{slope}, $PD_{intercept}$).
   iv) determine the median (PD_{median}) of all perpendicular distances to the appropriate 45 degree line (intercept error line or slope error line for absolute or relative scale respectively)
   v) calculate the bias for each laboratory (ie the distance from the centre along the appropriate 45 degree line) and if:
   <4.5 times PD_{median} select the PD to the 45 degree line
   other-wise select the lesser of the two PDs (PD_{slope} or $PD_{intercept}$)
   vi) determine the average of all selected PD values less than 2.5 times the PD_{median} and use this average to estimate the average repeatability S_w (see reference 1).
   vii) set warning limits for repeatability = 2 times S_w
   viii) set control limits for repeatability = 3 times S_w
   ix) set warning limits for possible bias = 3 times S_w
   x) set control limits for possible bias = 4.5 times S_w

6. Code performance based on location of points on the diagram using LOTUS 123® program:

   i) in upper left or lower right quadrant (erratic)
   ii) in lower left or upper right quadrant (biased low or high)
   iii) on horizontal or vertical axis (out of control)
   iv) on diagonal line through origin (slope or standard problems)
   v) on diagonal line not through origin (intercept or blank problems)

7. Prepare summary table of performance assessment.

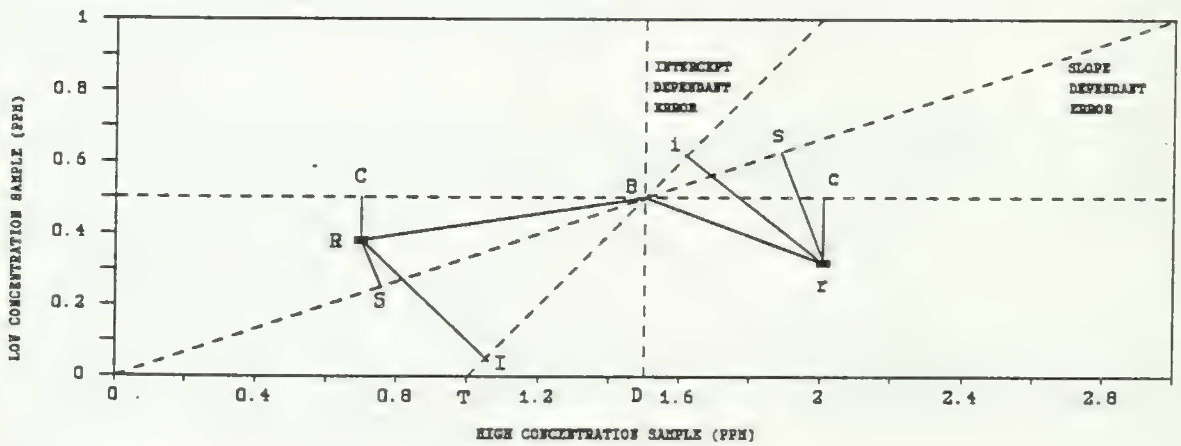
3. TRIGONOMETRIC COMPUTATIONS

NOTE: In this section medians are assumed to be the basis of evaluation. If targets were choosen to be the basis of evaluation then the word 'target' should be substituted for the word 'median' through-out this section.

For this discussion the higher concentration sample will be plotted on the X-axis and the lower concentration sample on the Y-axis. The MOE (LOTUS 123®) program automatically assigns the following scales:

Absolute scale	X-axis	0 - 2*median_{high}
	Y-axis	0 - 2*median_{low}
Relative scale	both axes	0% - 200%

FIGURE 3.1



In the diagrams (Figure 3.1 & 3.2) the point R corresponds to a pair of results and B is point of intersection of the two median lines. The intercept error line meets the X-axis at position T. The slope error line passes through the origin and B. Point D corresponds to higher concentration sample median.

<u>POSITIONING THE INTERCEPT ERROR LINE</u>

In all cases the intercept error line originates at T and passes through B.

Positioning of T is relatively easy for graphs in absolute scale. T is positioned such that TD equals BD (in concentration units).

The position of T in relative scale is given by

$$100 * \frac{(Median_{high} - Median_{low})}{Median_{high}}$$

TRIGONOMETRIC COMPUTATION OF THE MAGNITUDE OF RANDOM ERROR

The computation of the measure of the random error for each laboratory will depend on the position of the laboratory on the graph and on whether absolute or relative scales were used. These computations are best understood by referring to Figures 3.1 & 3.2. Figure 3.1 refers to those cases where the majority of the participants show errors that are slope independent. Figure 3.2 illustrates the case where errors are slope dependant. The length of RB is the magnitude of the total error. The perpendicular from R to the lower concentration sample median line falls on point C. I and S are points on the intercept error line and slope error line respectively where the appropriate perpendicular lines (RI, RS) from R meet these two lines. RI and RS corresponds to $PD_{intercept}$ and PD_{slope} respectively (section 2). Lower case and upper case characters in these diagrams correspond to pairs of results located in different zones on the graph.

The following general equations apply to all cases.

$$RC = ABS(MEDIAN_{LOW-SAMPLE} - RESULT_{LOW-SAMPLE})$$

$$BC = ABS(MEDIAN_{HIGH-SAMPLE} - RESULT_{HIGH-SAMPLE})$$

$$RB = \sqrt{(RC^2 + BC^2)}$$

$$\angle RBC = \theta = \text{arc sin } \left(\frac{RC}{RB}\right)$$

FOR ERRORS NOT CONCENTRATION DEPENDANT (FIGURE 3.1)

$$Let\ \angle RBI = \rho$$

$$Let\ \angle SBC = \phi$$

$$\phi = \arc\tan\left(\frac{median_{low-sample}}{median_{high-sample}}\right)$$

$$Let\ \angle SBR = \eta$$

When a laboratory appears in the lower left or upper right quadrant,

$$\sin\rho = \sin(ABS\,(45 - \theta))$$

$$\sin\eta = \sin(ABS\,(\phi - \theta))$$

When a laboratory appears in the upper right or lower left quadrant, then

$$\sin\rho = \sin(\theta + 45)$$

$$\sin\eta = \sin(\phi + \theta)$$

In both cases, Intercept random error(RI) and Slope random error(RS) are given by:

$$RI = RB * \sin\rho$$

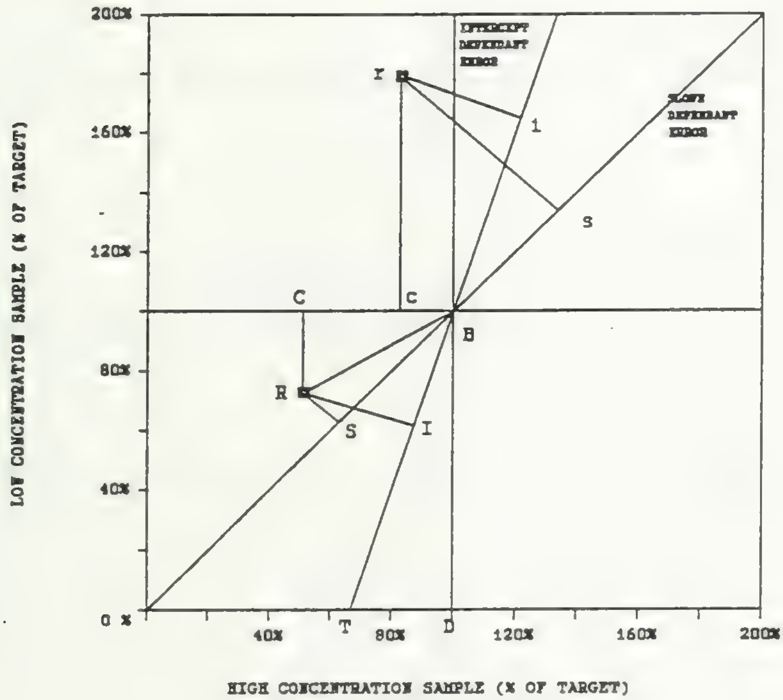
$$RS = RB * \sin \eta$$

The bias BI (along the 45 degree line) is given by

$$BI = RB * \cos \rho$$

<u>FOR ERRORS CONCENTRATION DEPENDANT (FIGURE 3.2)</u>

FIGURE 3.2



$$let\ \angle RBS = \lambda$$

$$Let\ \angle IBD = \sigma$$

$$\sigma = \arc \tan(\frac{DT}{DB})$$

$$Let\ \angle IBR = \omega$$

When a laboratory appears in the lower left or upper right quadrant,

$$\sin \lambda = \sin (ABS(45 - \theta))$$

$$\sin \omega = \sin (ABS((90-(\sigma+\theta)))$$

When a laboratory appears in the upper right or lower left quadrant,

$$\sin \lambda = \sin (45 + \theta)$$

$$\sin \omega = \sin (90-ABS(\sigma - \theta)$$

In both cases, Intercept random error (RI) and Slope random error (RS) are given by:

$$RI = RB * SIN\ \omega$$

$$RS = RB * SIN\ \lambda$$

The bias BS (along the 45 degree line) is given by

$$BS = RB * \cos \lambda$$

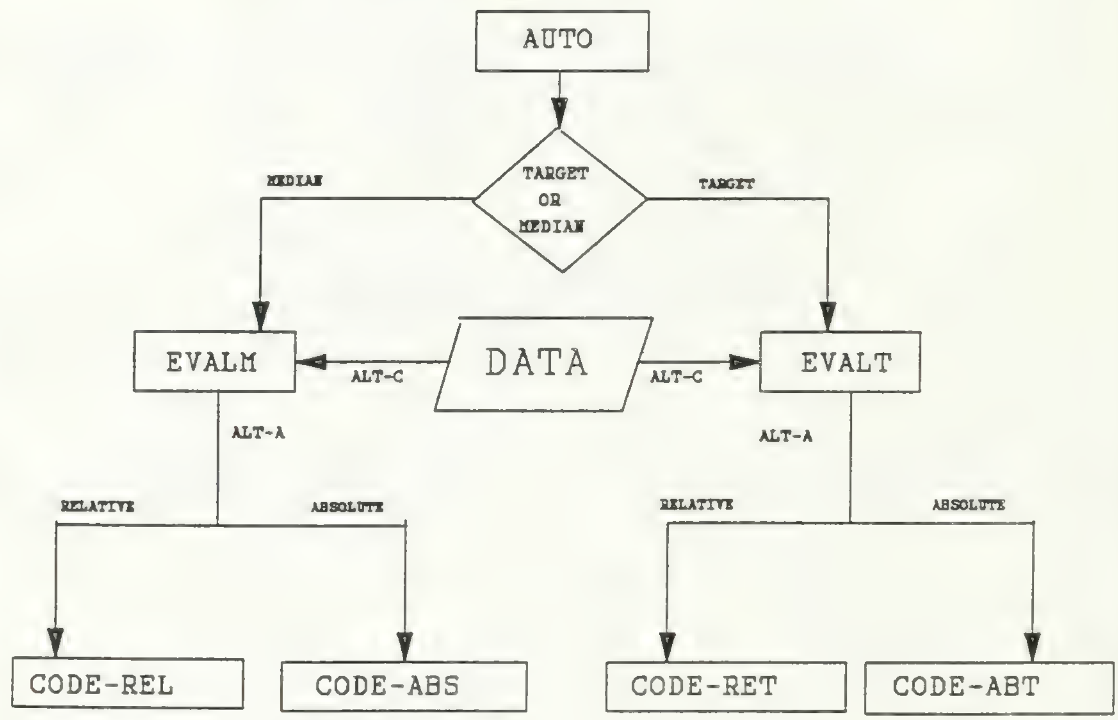
4. LOTUS 123® PROGRAMS

4.1 Overview

LOTUS 123® (version 2.1 or higher) is used to automate the majority of the steps involved in the evaluation procedure. A basic operational knowledge of LOTUS 123® is required to run the series of programs associated with this evaluation. In addition, a knowledge of LOTUS FREELANCE® or similar graphics software capable of importing 'pic' files is essential to generate graphs with 'acceptable performance' zones demarcated.

The step-wise summary (section 2) describes the various steps involved in the evaluation. These steps are grouped for convenience into a number of small programs. The inter-relationship among these programs is presented in the form of a flow diagram (Figure 4.1). Each of these programs is described below.

FIGURE 4.1



The starting program is called **'AUTO'**. This is a menu-driven program that allows you to choose either targets (or expected value) or medians as the basis for evaluation. Upon selection, the appropriate program will be loaded.

At this stage the data file is combined and the evaluation procedure is initiated.

On completion of the evaluation, a display of the evaluation diagram will appear on the screen. The diagram may be saved as a 'pic' file and the work sheet saved as a 'wk1' file.

The study findings are presented in both tabular as well as graphical forms. For the former, relevant portions of the spreadsheet may be printed. For the latter, 'pic' files are imported into LOTUS FREELANCE®, scales suitably adjusted and acceptable performance zones marked.

4.2 Data Format

This program at present is limited to a maximum of forty participants. A similar program to include larger numbers (up to 100) is being developed.

The first step is to ensure that the data is in a suitable LOTUS 123® format. As described earlier in section 2 the procedure evaluates a pair of analytical results from each participant. This pair of results and the laboratory identification (lab code) constitute the data set for each laboratory. The first data set is entered in Row 3 (Rows 1 & 2 are reserved for any titles that needs to be entered). The lab code is entered in column A, followed by the result of the lower concentration sample (in column B). The result of the higher concentration sample is entered in column C. The rest of the data sets are entered in a similar fashion on subsequent rows. An example of a suitable data format (File DATA1) is provided on the program diskette.

Note: Since the program is limited to 40 participants, the data file cannot exceed row 43.

Save the data file.

4.3 Program Execution

Retrieve the file **"AUTO.wk1."** A menu will appear. Choose either target or median. The appropriate file will be retrieved and the cursor will be in cell I1. **Combine** your data file by pressing keys **ALT** & **C** simultaneously. Enter the data file name (include the path if data file is in a different directory) when requested and press RETURN key. On completion the data file is combined with the program file and the cursor will be in cell I1.

NOTE: Ensure that program files are placed in the default directory.

Press keys **ALT** & **A** simultaneously. Now relax! the program will take about 15 minutes to complete (depending on the number of participants, speed of your computer, variability of your data etc.,). On completion of the program you will see a graph on the screen. At this stage you may want to enter titles, make other changes and save the graph as a 'PIC' file.

Exit the graph menu to the spreadsheet and save the spreadsheet. Considerable disk space may be saved by extracting only the only relevant information (cells A1 to BL60) instead of saving the entire spreadsheet.

On the finished spreadsheet many of the columns are hidden. Displayed columns from J to AY have all the information necessary for the tabular summary. Columns J & K contain the raw data. Columns L & M contain results of laboratories that were included in the final selection for the estimation of various 'between laboratory statistics' for both samples. The total error (see section 2) for non acceptable participants is listed on column AW. Evaluation findings for each participant are listed in columns AX and AY.

FIGURE 4.2

MOE INTERLABORATORY STUDY

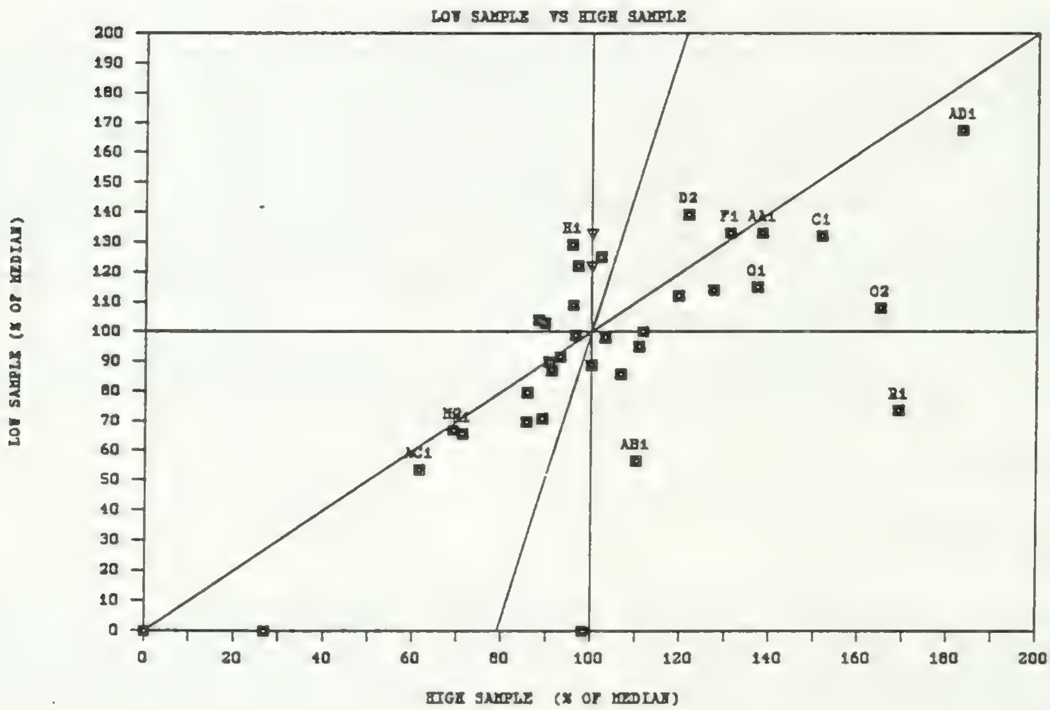


Figure 4.2 is a typical 'PIC' graph that will appear on the screen. The graph is divided into four quadrants. Each participant is represented by a rectangular symbol. The diagonal line that goes through the origin represents the slope dependant bias. The other diagonal line represents the intercept dependant bias. The laboratories that have exceeded the warning limits are identified. The two triangular symbols on the Y-axis correspond to 2 & 3 times repeatability (S_w) from the centre respectively. These symbols serve as markers for drawing circles.

4.4 LOTUS FREELANCE® Refinement of 'pic' graphs.

The 'pic' file is imported into LOTUS FREELANCE® to generate graphs with proper identification of the bias lines and acceptable performance zones. As mentioned earlier, a good working knowledge of LOTUS FREELANCE® is required to manipulate the various steps involved in producing a suitable graphical presentation.

A brief outline of the major steps involved is given below.

a) Import 'pic' graphs into LOTUS FREELANCE®

b) Select all (SELECT;ALL).

c) Scale down one axis of the graph so that the acceptable repeatability zone remains circular (EDIT; SIZE; NON-UNIFORM; etc). This will depend on whether evaluation was performed in absolute(concentration units) or relative (percentages of medias/targets) scale. This is a **critical step** and must be performed as accurately as possible.

   i) When performed in absolute scale, reduce the height (y-axis) of the graph until the angle between the intercept error line and the x-axis is equal to 45 degrees. The unit lengths of both axis are identical in absolute (concentration) units.

   ii) When performed in relative scale, reduce the width (x-axis) of the graph until the angle between the slope error line and the x-axis is equal to 45 degrees. The unit lengths of both axis are identical in relative scales.

d) Draw circles with the point of intersection of the two median(or target) lines as the centres. The radus for the circle extend from the centre to the triangular symbols on the Y axis.

e) Draw two bows, one on the lower left quadrant and the other on the upper right quadrant. The three points for each bow are the points of intersection of the outer circle with the two median (or target) line and the 45 degree line.

f) Select the outer circle (SELECT; NONE; SELECT; CYCLE; press arrow key on the number pad until outer circle is highlighted, press enter). Delete outer circle (REARRANGE; DELETE). The bows may appear fuzzy. The graph may be redrawn (VIEW; FULL) if you so desire. Select the two triangular symbols used to mark the radii and delete (REARRANGE; DELETE).

g) If more than one lab appears in the same area on the graph, the laboratory identification may not be legible. In such cases move the lab codes manually until the laboratory identification is clear.

h) Label the two bias lines.

i) Save file as a 'drw' file.

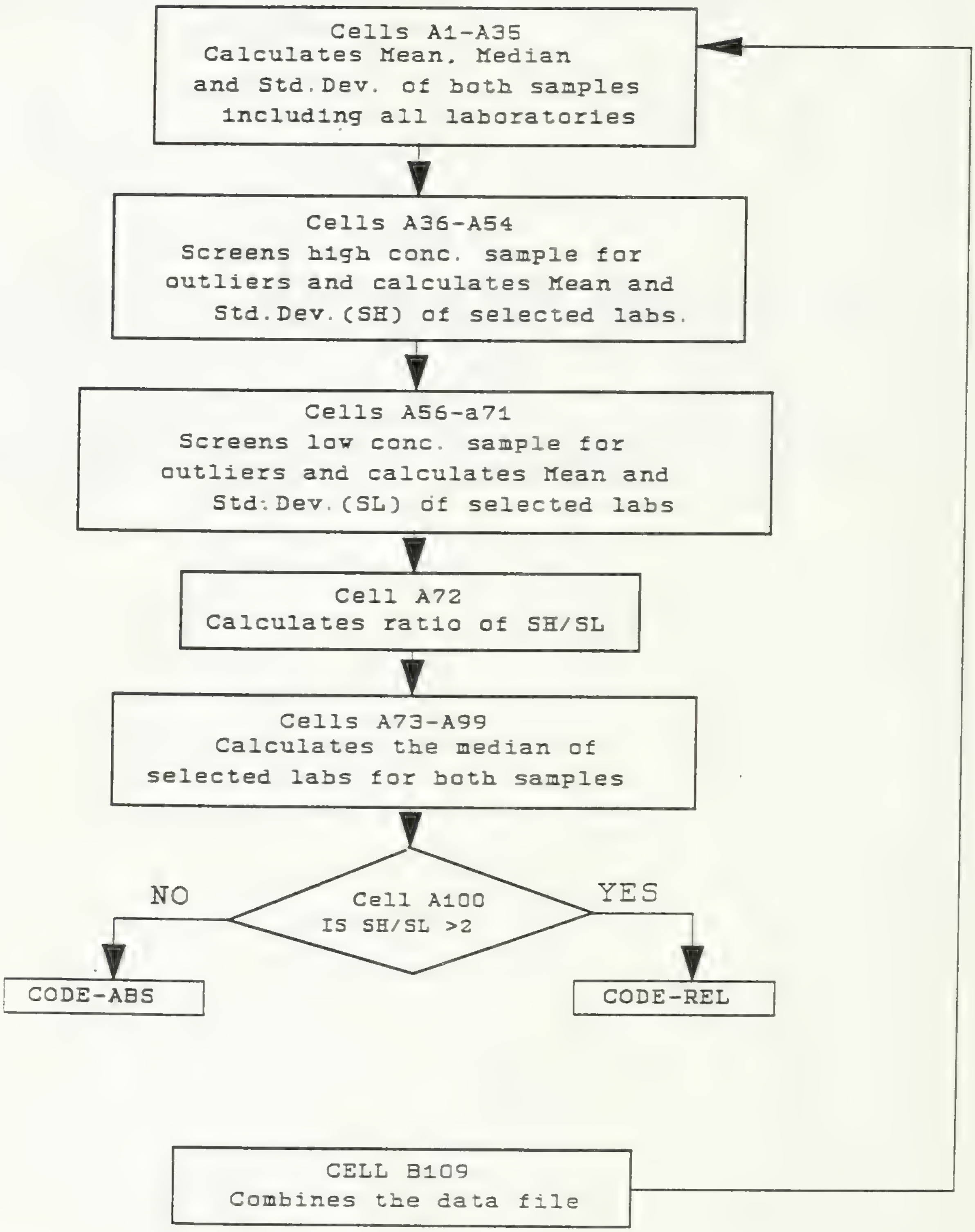
4.5 Listing of LOTUS 123® programs

The programs 'EVALM' , 'CODE-ABS' and 'CODE-REL' are listed line by line in sub-sections 4.5.1 to 4.5.3. Also included in the form of flow-diagrams an explanation of the fucnctions of various segments of each program.

The programs 'EVALT', 'CODE-ABT' & 'CODE-RET' of the target mode are very similar to their counter parts of the median mode. Therefore these programs have not been duplicated.

4.5.1 EVALM

EVALM


Cells A1-A35
Calculates Mean, Median
and Std.Dev. of both samples
including all laboratories
Cells A36-A54
Screens high conc. sample for
outliers and calculates Mean and
Std.Dev.(SH) of selected labs.
Cells A56-a71
Screens low conc. sample for
outliers and calculates Mean and
Std.Dev.(SL) of selected labs
Cell A72
Calculates ratio of SH/SL
Cells A73-A99
Calculates the median of
selected labs for both samples
NO
Cell A100
IS SH/SL >2
YES
CODE-ABS
CODE-REL
CELL B109
Combines the data file

EVALM

ROW	Column A	Column C	Column D	Column E
1	/dfh3..h43~1~1~45~			
2	{goto}I46~Std.dev.~{right}~@std(j3..j43)~			
3	{right}~@std(K3..K43)~{goto}i47~			
4	Mean~{right}~@avg(j3..j43)~{right}~@avg(k3..k43)~			
5	{goto}j65~			
6	{goto}i48~median~			
7	{down}~'# of labs~			
8	/DSDh3.M43~Pj43..j43~D~G			
9	{GOTO}N3~			
10	@IF(j3>0,1,0)~			
11	/CN3..N3~N3..N43~			
12	{GOTO}j49~@SUM(N43..N3)~			
13	/RVj49..j49~j49..j49~			
14	{GOTO}L70~@MOD(j49,2)~			
15	{down}~@int((j49/2)+.5)~			
16	{GOTO}j3~{DOWN l71-1}			
17	/c{down}~l73..l74~			
18	{goto}l75~@avg(l73..l74)~			
19	{Goto}j48~@if(l70=0,+l75,+l73)~			
20	/rvj48..j48~j48..j48~			
21	/DSPk43..k43~D~G			
22	{GOTO}N3~			
23	@IF(k3>0,1,0)~			
24	/CN3..N3~N3..N43~			
25	{GOTO}k49~@SUM(N43..N3)~			
26	/RVk49..k49~k49..k49~			
27	{GOTO}L70~@MOD(k49,2)~			
28	{down}~@int((k49/2)+.5)~			
29	{GOTO}k3~{DOWN l71-1}			
30	/c{down}~l73..l74~			
31	{goto}l75~@avg(l73..l74)~			
32	{Goto}k48~@if(l70=0,+l75,+l73)~			
33	/rvk48..k48~k48..k48~			
34	/dsph3..h3~a~g~			
35	/wdcn1..n1~			

EVALM(cont.)

ROW	Column A	Column C	Column D	Column E
36	{goto}m3~/re13..m45~		seed	{let diff,@abs(left-target):value}
37	/rncdiff~k70~/rnctop~m3~			{if diff<.100001*target}/cleft~~
38	/rncrange~m3..m43~			/rncleft~{down}~
39	/rncsd~m46..m46~			{down}
40	/rnctarget~k48..k48~			
41	/rncval~m80..m80~			
42	/rncleft~k3..k3~		iter	{let diff,@abs(left-target):value}
43	{for e80,1,41,1,seed}			{if diff<3.00001*val}/cleft~~
44	{down 2}~@std(range)~			/rncleft~{down}~
45	{down}~@avg(range)~			{down}
46	/rvsd~val~			
47	/rncnumber~m45~			
48	{let number,1+number}		comp	{if val=sd}{branch lo-sam}
49	/rncleft~k3..k3~			{let val,sd:value}
50	{goto}top~/rerange~			/rerange~
51	{for e80,1,41,1,iter}			{branch cont}
52	{down 2}~@std(range)~			
53	{down}~@avg(range)~			
54	{branch comp}			
55	{let val,sd/k48*j48:value}		second	{if val=sd}{branch label}
56	{let val,sd/k48*j48:value}			{let val,sd:value}
57	/rvm45..m47~m45..m47~			/rerange~
58	/rncdiff~j70~/rnctop~l3~			{branch low}
59	/rncrange~l3..l43~			
60	/rncsd~l46..l46~			
61	/rnctarget~j48..j48~			
62	/rncnumber~l45~			
63	{let number,1+number}		stop	{goto}a2~ok-ok~
64	{goto}top~/rerange~			
65	/rncleft~j3..j3~			
66	{for E80,1,41,1,iter}			
67	{down 2}~@std(range)~			
68	{down}~@avg(range)~			
69	{branch second}			

EVALM(cont.)

LINE	Column A	Column C	Column D	Column E
70	/rvl45..l47~m45..m47~			
71	{goto}l1~low-sam~{right}hi-sam~			
72	{goto}i50~SH/SL= ~{right}+M46/l46~			
73	/DSPL43..L43~D~G			
74	{GOTO}N3~			
75	@IF(L3>0,1,0)~			
76	/CN3..N3~N3..N43~			
77	{GOTO}L49~@SUM(N43..N3)~			
78	/RVL49..L49~L49..L49~			
79	{GOTO}L70~@MOD(L49,2)~			
80	{down}~@int((l49/2)+.5)~			
81	{GOTO}L3~{DOWN l71-1}			
82	/c{down}~l73..l74~			
83	{goto}l75~@avg(l73..l74)~			
84	{Goto}l48~@if(l70=0,+l75,+l73)~			
85	/rvl48..l48~l48..l48~			
86	/DSPm43..m43~D~G			
87	{GOTO}N3~			
88	@IF(m3>0,1,0)~			
89	/CN3..N3~N3..N43~			
90	{GOTO}m49~@SUM(N43..N3)~			
91	/RVm49..m49~m49..m49~			
92	{GOTO}L70~@MOD(m49,2)~			
93	{down}~@int((m49/2)+.5)~			
94	{GOTO}m3~{DOWN l71-1}			
95	/c{down}~l73..l74~			
96	{goto}l75~@avg(l73..l74)~			
97	{Goto}m48~@if(l70=0,+l75,+l73)~			
98	/rvm48..m48~m48..m48~			
99	/DSPh43..h43~a~G			
100	{if j50>2}{branch C101}			
101	{goto}a110~	{goto}a110~		
102	/fccecode-abs.wk1~	/fccecode-rel.wk1~		
103	{branch b110}	{branch b110}		
109		/fcce{?}~~/rnc\a~a1~		

4.5.2 CODE-ABS

CODE-ABS

Cells B1-B8
Calculates the Total Error

↓

Cells B9-B21
Calculates PD's to slope and
intercept error lines
select PD to intercept line
repeat steps 1-20 to all labs

↓

Cells B22-B32
Determines the median of PD's to
the intercept error line

↓

Cells G18-G24
Calculates bias, selects appropriate PD's
calculates average PD and estimates
average repeatability Sw

↓

Cells B33-B98
Evaluates each pair of data
classifies errors (lines 37-58) &
assigns error codes (lines 59-98)

↓

Cells B99-B113
Calculates the appropriate variables,
define plotting coordinates, titles etc.,
and plots diagram

CODE-ABS

ROW	B	G
1	{goto}n3~	
2	@IF(j50>2,+J3*100/$L$48,+j3)~{Right}~	
3	@IF(j50>2,+k3*100/k48,+k3)~	
4	/cn3..o3~n3..o43~	
5	/rff3~n3..o43~	
6	{goto}p2~Tot.error~{right}theta~{right}slope^~{right}int'pt^~	
7	{right 2}slope.er.~{right}int'pt.er.~	
8	{goto}p3~@IF(J3=0,"-",@IF(K3=0,"-",@sqrt(((j3-l48)^2)+((k3-m48)^2))))~	
9	{goto}n60~@atan(l48/m48)*180/@pi~	
10	{goto}q3~@asin(@INT(@abs(j3-$L$48)/p3*10000)/10000)*180/@pi~	
11	{goto}t3~	
12	@if(j3<=l48#and#k3<=m48,1,@if(j3>=l48#and#k3>=m48,2,0))~	
13	{goto}r3~@if(t3>0,@abs(q3-n60),q3+n60)~	
14	{right}~@if(t3>0,@abs(q3-45),q3+45)~	
15	/rff1~q3..s3~	
16	{goto}u3~@sin(r3*@pi/180)*p3~	
17	{Right}~@sin(s3*@pi/180)*p3~	/rew3..x43~
18	{right}~@if(j3=0,"",@if(k3=0,"",v3))~	{goto}w3~@if(j3=0,"",@if(k3=0,"",@IF(P3=0,0,@IF(@COS(S3*@PI/180)*P3<4.5*$J$52,V3,@if(v3<u3,v3,u3)))))~
19	{right}~@if(@isnumber(w3)=1,1,0)~	{GOTO}X3~@IF(j3=0,0,@if(k3=0,0,@if(W3>3*$J$52,"",1)))~
20	/rff4~u3..w3~	{GOTO}Y3~@IF(W3>3*$J$52,"",w3)~
21	/cp3..x3~p3..x43~	/Cw3..Y3~w3..Y43~
22	/rvw3..w43~w3..w43~	{GOTO}X46~@SUM(X3..X43)~/C~Y46..Y46~
23	{goto}x60~@sum(x3..x43)~/rvx60..x60~x60..x60~	{GOTO}J51~+Y46/X46*1.2533~
24	/dsdh3..x43~pw3..w43~d~g	/rvj51..j52~j51..j52~
25	{GOTO}w70~@MOD(x60,2)~	{BRANCH B142}
26	{down}~@int((x60/2)+.5)~	
27	{GOTO}w3~{DOWN w71-1}	

ROW	B	G
28	/c{down}~w73..w74~	
29	{goto}w75~@avg(w73..w74)~	
30	{Goto}j52~@if(w70=0,+w75,+w73)~	
31	/rvj52..j52~j52..j52~	
32	{BRANCH G126}	
33	/dsdh3..x43~ph3..h43~a~g	
34	{GOTO}I51~Sw~	
35	{branch b146}	
36		
37	{goto}z3~+@IF(@ISNUMBER(P3)=0,"",@int(p3/j51*10)/10)~{right}+u3/j51~{right}+v3/j51 ~/rff1~z3..ab3~	
38	{right}@IF(@ABS(@ABS(j3)-$L$48)/j51<2,1,@IF(@ABS(@ABS(k3)-$M$48)/j51<2,1,0))~	
39	{right}@if(t3=1#OR#t3=2,0,@if(p3=0,0,@if(z3<=2,1,@if(z3>2#and#z3<=3,2,@if(ac3=1,15,16)))))~	
40	{right}@if(t3=2#or#t3=0,0,@IF(z3<=4.5,0,@if(q3<45,0,@IF(Ab3<1,4,@if(ac3=1,15,@IF(Ab3>1#A ND#Ab3<2,3,8))))))~	
41	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>$N$60,0,@IF(AA3<1,6,@if(aC3=1,15,@IF(AA3> 1#AND#AA3<2,5,8))))))~	
42	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AB3>AA3,0,@IF(AB3< 1,4,@IF(AB3>1#AND#AB3<2,3,7)))))))~	
43	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AA3>AB3,0,@IF(AA3< 1,6,@IF(AA3>1#AND#AA3<2,5,7)))))))~	
44	{right}@if(t3=1#or#t3=0,0,@IF(z3<=4.5,0,@if(q3<45,0,@IF(Ab3<1,10,@if(ac3=1,15,@IF(Ab3>1# AND#Ab3<2,9,14))))))~	
45	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>$N$60,0,@IF(AA3<1,12,@if(aC3=1,15,@IF(AA3 >1#AND#AA3<2,11,14))))))~	
46	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AB3>AA3,0,@IF(AB3< 1,10,@IF(AB3>1#AND#AB3<2,9,13)))))))~	
47	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AA3>AB3,0,@IF(AA3< 1,12,@IF(AA3>1#AND#AA3<2,11,13)))))))~	
48	{right}@if(t3=2#or#t3=0,0,@IF(z3<=3#OR#Z3>4.5,0,@if(q3<45,0,@IF(Ab3<1,18,@if(ac3=1,29,@I F(Ab3>1#AND#Ab3<2,17,22))))))~	
49	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>$N$60,0,@IF(AA3<1,20,@if(aC3=1,29 ,@IF(AA3>1#AND#AA3<2,19,22))))))~	
50	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AB3>AA3,0, @IF(AB3<1,18,@IF(AB3>1#AND#AB3<2,17,21))))))~	
51	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AA3>AB3,0, @IF(AA3<1,20,@IF(AA3>1#AND#AA3<2,19,21))))))~	

CODE-ABS(cont.)

ROW	B
52	{right}@if(t3=1#or#t3=0,0,@IF(z3<=3#OR#Z3>4.5,0,@if(q3<45,0,@IF(Ab3<1,24,@if(ac3=1,29,@IF(Ab3>1#AND#Ab3<2,23,28))))))~
53	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>$N$60,0,@IF(AA3<1,26,@if(aC3=1,29,@IF(AA3>1#AND#AA3<2,25,28))))))~
54	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AB3>AA3,0,@IF(AB3<1,24,@IF(AB3>1#AND#AB3<2,23,27))))))~
55	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3<=$N$60#OR#Q3>=45,0,@IF(AA3>AB3,0,@IF(AA3<1,26,@IF(AA3>1#AND#AA3<2,25,7))))))~
56	{RIGHT}@IF(T3=0,0,@IF(Z3<=3,1,0))~
57	{right}~@IF(@ISNUMBER(P3)=0,0,@sum(aD3..aU3))~
58	{RIGHT}@IF(AV3>1,Z3,"")~/RFF1~AW3..AW3~
59	/cz3..aW3~z3..aW43~/rnccode~b173..b174~
60	/rvav3..aw43~av3..aw43~
61	/RNCLEFT~AV3..AV3~{goto}aX3~
62	{for a200,1,41,1,B174}
63	{branch b207}
65	{IF LEFT=1}A~{RIGHT}ACCEPTABLE PERFORMANCE~{LEFT}
66	{IF LEFT=2}AI~{RIGHT}WARNING SLIGHT IMPRECISION~{LEFT}
67	{IF LEFT=3}Li~{RIGHT}BIASED LOW, POSSIBLE INTERCEPT PROBLEM~{LEFT}
68	{IF LEFT=4}LI~{RIGHT}BIASED LOW, PROBABLE INTERCEPT PROBLEM~{LEFT}
69	{IF LEFT=5}Ls~{RIGHT}BIASED LOW, POSSIBLE SLOPE PROBLEM~{LEFT}
70	{IF LEFT=6}LS~{RIGHT}BIASED LOW, PROBABLE SLOPE PROBLEM~{LEFT}
71	{IF LEFT=7}L~{RIGHT}BIASED LOW~{LEFT}
72	{IF LEFT=8}Le~{RIGHT}BIASED LOW OR ERRATIC~{LEFT}
73	{IF LEFT=9}Hi~{RIGHT}BIASED HIGH, POSSIBLE INTERCEPT PROBLEM~{LEFT}
74	{IF LEFT=10}HI~{RIGHT}BIASED HIGH, PROBABLE INTERCEPT PROBLEM~{LEFT}
75	{IF LEFT=11}Hs~{RIGHT}BIASED HIGH, POSSIBLE SLOPE PROBLEM~{LEFT}
76	{IF LEFT=12}HS~{RIGHT}BIASED HIGH, PROBABLE SLOPE PROBLEM~{LEFT}
77	{IF LEFT=13}H~{RIGHT}BIASED HIGH~{LEFT}
78	{IF LEFT=14}He~{RIGHT}BIASED HIGH OR ERRATIC~{LEFT}
79	{IF LEFT=15}OC~{RIGHT}ONE RESULT ERRATIC~{LEFT}
80	{IF LEFT=16}ER~{RIGHT}BOTH RESULTS ERRATIC~{LEFT}
81	{IF LEFT=17}WLi~{RIGHT}WARNING:BIASED LOW, POSSIBLE INTERCEPT PROBLEM~{LEFT}

ROW	B
82	{IF LEFT=18}WLI~{RIGHT}WARNING:BIASED LOW, PROBABLE INTERCEPT PROBLEM~{LEFT}
83	{IF LEFT=19}WLs~{RIGHT}WARNING:BIASED LOW, POSSIBLE SLOPE PROBLEM~{LEFT}
84	{IF LEFT=20}WLS~{RIGHT}WARNING:BIASED LOW, PROBABLE SLOPE PROBLEM~{LEFT}
85	{IF LEFT=21}WL~{RIGHT}WARNING:BIASED LOW~{LEFT}
86	{IF LEFT=22}WLe~{RIGHT}WARNING:BIASED LOW OR ERRATIC~{LEFT}
87	{IF LEFT=23}WHi~{RIGHT}WARNING:BIASED HIGH, POSSIBLE INTERCEPT PROBLEM~{LEFT}
88	{IF LEFT=24}WHI~{RIGHT}WARNING:BIASED HIGH, PROBABLE INTERCEPT PROBLEM~{LEFT}
89	{IF LEFT=25}WHs~{RIGHT}WARNING:BIASED HIGH, POSSIBLE SLOPE PROBLEM~{LEFT}
90	{IF LEFT=26}WHS~{RIGHT}WARNING:BIASED HIGH, PROBABLE SLOPE PROBLEM~{LEFT}
91	{IF LEFT=27}WH~{RIGHT}WARNING:BIASED HIGH~{LEFT}
92	{IF LEFT=28}WHe~{RIGHT}WARNING:BIASED HIGH OR ERRATIC~{LEFT}
93	{IF LEFT=29}WOC~{RIGHT}WARNING:ONE RESULT ERRATIC~{LEFT}
94	{IF LEFT=30}WER~{RIGHT}WARNING:BOTH RESULTS ERRATIC~{LEFT}
95	/RNCLEFT~{DOWN}~
96	{DOWN}
98	/wchn3..av3~
99	{goto}be3~@if(av3>1,i3,"")~{right}+j3~{right}+k3~
100	/cbe3..bg3~be3..bg43~
101	{goto}bg44~+m48~{down}+m48~{right}0~{up}2*l48~
102	{goto}bg46~0~{right 2}+l48~
103	{goto}bg47~2*m48~{right 2}+l48~
104	{goto}bg48~0~{right 3}0~
105	{goto}bg49~2*m48~{right 3}2*l48~
106	{goto}bg50~+m48-l48~{right 4}0~
107	{goto}bg51~+m48+l48~{right 4}~+l48*2~
108	{goto}bg52~+m48~{right 5}+l48+(2*j51)~
109	{goto}bg53~+m48~{right 5}+l48+(3*j51)~
110	/grgtxxbg3..bg53~abf3..bf53~bbh3..bh53~cbi3..bi53~dbj3..bj53~ebk3..bk53~fbl3..bl53~
111	ocfglasfsqsymuL48*2~qsxmuM48*2~q
112	dabe3..be53~aq
113	tfINTERLABORATORY STUDY: K-S PROCEDURE ~TS LOW CONC.SAMPLE VS HIGH CONC. SAMPLE ~TXHIGH CONC.SAMPLE ~TY LOW CONC. SAMPLE ~QV

4.5.3 CODE-REL

CODE-REL

Cells B1-B9
Transform results into percentages of median
Calculates the Total Error

Cells B9-B22
Calculates PD's to slope and
intercept error lines
select PD to slope line
repeat steos 1-21 to all labs

Cells B22-B33
Determines the median of PD's to
the intercept error line

Cells G18-G24
Calculates bias, selects appropriate PD's
calculates average PD and estimates
average repeatability Sw

Cells B34-B100
Evaluates each pair of data
classifies errors (lines 39-60) &
assigns error codes (lines 61-100)

Cells B101-B115
Calculates the appropriate variables,
define plotting coordinates, titles etc.,
and plots diagram

CODE-REL

LINE	B	G
1	{goto}n3~	
2	@IF(j50>2,+J3*100/$L$48,+j3)~{Right}~	
3	@IF(j50>2,+k3*100/k48,+k3)~	
4	/cn3..o3~n3..o43~	
5	/rff0~n3..o43~	
6	{goto}p2~Tot.error~{right}theta~{right}slope^~{right}int'pt^~	
7	{right 2}slope.er.~{right}int'pt.er.~	
8	{goto}p3~@IF(J3=0,"-",@IF(K3=0,"-",@sqrt(((N3-100)^2)+((O3-100)^2))))~	
9	{GOTO}N59~+((M48-L48)/M48)~	
10	{goto}n60~@atan((1-n59))*180/@pi~	
11	{goto}q3~@asin(@INT(@abs(n3-100)/p3*10000)/10000)*180/@pi~	
12	{goto}t3~	
13	@if(n3<=100#and#o3<=100,1,@if(n3>100#and#o3>100,2,0))~	
14	{goto}r3~@if(t3>0,@abs(45-q3),q3+45)~	
15	{right}~@if(t3>0,@abs(90-(q3+n60)),90-@abs(q3-n60))~	
16	/rff1~q3..s3~	
17	{goto}u3~@if(p3=0,0,@sin(r3*@pi/180)*p3)~	/REW3..X3~
18	{Right}~@if(p3=0,0,@sin(s3*@pi/180)*p3)~	{GOTO}W3~@IF(j3=0,"",@IF(K3=0,"",@IF(P3=0,0,@IF(@COS(R3*@PI/180)*p3<4.5*$J$52,u3,@IF(u3<v3,u3,v3)))))~
19	{right}~@if(j3=0,"",@if(k3=0,"",u3))~	{GOTO}X3~@IF(j3=0,0,@if(k3=0,0,@if(W3>3*$J$52,"",1)))~
20	{right}~@if(@isnumber(w3)=1,1,0)~	{GOTO}Y3~@IF(W3>3*$J$52,"",w3)~
21	/rff4~u3..w3~	/Cw3..Y3~w3..Y43~
22	/cp3..x3~p3..x43~	{GOTO}X46~@SUM(X3..X43)~/C~Y46..Y46~
23	/rvw3..w43~w3..w43~	{GOTO}J51~+Y46/X46*1.2533~
24	{goto}x60~@sum(x3..x43)~	{BRANCH B143}
25	/dsdh3..x43~pw3..w43~d~g	
26	{GOTO}w70~@MOD(x60,2)~	
27	{down}~@int((x60/2)+.5)~	
28	{GOTO}w3~{DOWN w71-1}	

CODE-REL(cont.)

LINE	B	G
29	/c{down}~w73..w74~	
30	{goto}w75~@avg(w73..w74)~	
31	{Goto}j52~@if(w70=0,+w75,+w73)~	
32	/RVJ52..J52~J52..J52~	
33	{branch g126}	
34	/rvj51..j52~j51..j52~	
35	/dsdh3..x43~ph3..h43~a~g	
36	{GOTO}I51~Sw~{RIGHT 2}%~	
37	{branch b148}	
39	{goto}z3~+@int(p3/j51*10)/10~{right}+u3/j51~{right}+v3/j51~/rff1~z3..ab3~	
40	{right}@IF(@ABS(n3-100)/j51<2,1,@IF(@ABS(o3-100)/j51<2,1,0))~	
41	{right}@if(t3=1#OR#t3=2,0,@if(p3=0,0,@if(z3<=2,1,@if(z3>2#and#z3<=3,2,@if(ac3=1,15,16)))))~	
42	{right}@if(t3=2#or#t3=0,0,@IF(z3<=4.5,0,@if(q3<(90-$N$60),0,@IF(Ab3<1,4,@if(ac3=1,15,@IF(Ab3>1#AND#Ab3<2,3,8))))))~	
43	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>45,0,@IF(AA3<1,6,@if(aC3=1,15,@IF(AA3>1#AND#AA3<2,5,8))))))~	
44	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AB3>AA3,0,@IF(AB3<1,4,@IF(AB3>1#AND#AB3<2,3,7))))))~	
45	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AA3>AB3,0,@IF(AA3<1,6,@IF(AA3>1#AND#AA3<2,5,7))))))~	
46	{right}@if(t3=1#or#t3=0,0,@IF(z3<=4.5,0,@if(q3<(90-$N$60),0,@IF(Ab3<1,10,@if(ac3=1,15,@IF(Ab3>1#AND#Ab3<2,9,14))))))~	
47	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>45,0,@IF(AA3<1,12,@if(aC3=1,15,@IF(AA3>1#AND#AA3<2,11,14))))))~	
48	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AB3>AA3,0,@IF(AB3<1,10,@IF(AB3>1#AND#AB3<2,9,13))))))~	
49	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AA3>AB3,0,@IF(AA3<1,12,@IF(AA3>1#AND#AA3<2,11,13))))))~	
50	{right}@if(t3=2#or#t3=0,0,@IF(z3<=3#OR#Z3>4.5,0,@if(q3<(90-$N$60),0,@IF(Ab3<1,18,@if(ac3=1,29,@IF(Ab3>1#AND#Ab3<2,17,22))))))~	
51	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>45,0,@IF(AA3<1,20,@if(aC3=1,29,@IF(AA3>1#AND#AA3<2,19,22))))))~	
52	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AB3>AA3,0,@IF(AB3<1,18,@IF(AB3>1#AND#AB3<2,17,21))))))~	
53	{right}@if(T3=2#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AA3>AB3,0,@IF(AA3<1,20,@IF(AA3>1#AND#AA3<2,19,21))))))~	

CODE-REL(cont.)

LINE	B	G
54	{right}@if(t3=1#or#t3=0,0,@IF(z3<=3#OR#Z3>4.5,0,@if(q3<(90-$N$60),0,@IF(Ab3<1,24,@if(ac3=1,29,@IF(Ab3>1#AND#Ab3<2,23,28))))))~	
55	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>45,0,@IF(AA3<1,26,@if(aC3=1,29,@IF(AA3>1#AND#AA3<2,25,28))))))~	
56	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AB3>AA3,0,@IF(AB3<1,24,@IF(AB3>1#AND#AB3<2,23,27))))))~	
57	{right}@if(T3=1#or#T3=0,0,@IF(Z3<=3#OR#Z3>4.5,0,@if(q3>=(90-$N$60)#OR#Q3<=45,0,@IF(AA3>AB3,0,@IF(AA3<1,26,@IF(AA3>1#AND#AA3<2,25,7))))))~	
58	{RIGHT}@IF(T3=0,0,@IF(Z3<=3,1,0))~	
59	{right}~@IF(@ISNUMBER(P3)=0,0,@sum(aD3..aU3))~	
60	{RIGHT}@IF(AV3>1,Z3,"")~/RFF1~AW3..AW3~	
61	/cz3..aW3~z3..aW43~/rnccode~b171..b171~	
62	/rvav3..aw43~av3..aw43~	
63	/RNCLEFT~AV3..AV3~{goto}aX3~	
64	{for a200,1,41,1,b176}	
65	{branch b209}	
67	{IF LEFT=1}A~{RIGHT}ACCEPTABLE PERFORMANCE~{LEFT}	
68	{IF LEFT=2}AI~{RIGHT}WARNING SLIGHT IMPRECISION~{LEFT}	
69	{IF LEFT=3}Li~{RIGHT}BIASED LOW, POSSIBLE INTERCEPT PROBLEM~{LEFT}	
70	{IF LEFT=4}LI~{RIGHT}BIASED LOW, PROBABLE INTERCEPT PROBLEM~{LEFT}	
71	{IF LEFT=5}Ls~{RIGHT}BIASED LOW, POSSIBLE SLOPE PROBLEM~{LEFT}	
72	{IF LEFT=6}LS~{RIGHT}BIASED LOW, PROBABLE SLOPE PROBLEM~{LEFT}	
73	{IF LEFT=7}L~{RIGHT}BIASED LOW~{LEFT}	
74	{IF LEFT=8}Le~{RIGHT}BIASED LOW OR ERRATIC~{LEFT}	
75	{IF LEFT=9}Hi~{RIGHT}BIASED HIGH, POSSIBLE INTERCEPT PROBLEM~{LEFT}	
76	{IF LEFT=10}HI~{RIGHT}BIASED HIGH, PROBABLE INTERCEPT PROBLEM~{LEFT}	
77	{IF LEFT=11}Hs~{RIGHT}BIASED HIGH, POSSIBLE SLOPE PROBLEM~{LEFT}	
78	{IF LEFT=12}HS~{RIGHT}BIASED HIGH, PROBABLE SLOPE PROBLEM~{LEFT}	
79	{IF LEFT=13}H~{RIGHT}BIASED HIGH~{LEFT}	
80	{IF LEFT=14}He~{RIGHT}BIASED HIGH OR ERRATIC~{LEFT}	
81	{IF LEFT=15}OC~{RIGHT}ONE RESULT ERRATIC~{LEFT}	
82	{IF LEFT=16}ER~{RIGHT}BOTH RESULTS ERRATIC~{LEFT}	
83	{IF LEFT=17}WLi~{RIGHT}WARNING:BIASED LOW, POSSIBLE INTERCEPT PROBLEM~{LEFT}	

CODE-REL(cont.)

LINE	B	G
84	{IF LEFT=18}WLI~{RIGHT}WARNING:BIASED LOW, PROBABLE INTERCEPT PROBLEM~{LEFT}	
85	{IF LEFT=19}WLs~{RIGHT}WARNING:BIASED LOW, POSSIBLE SLOPE PROBLEM~{LEFT}	
86	{IF LEFT=20}WLS~{RIGHT}WARNING:BIASED LOW, PROBABLE SLOPE PROBLEM~{LEFT}	
87	{IF LEFT=21}WL~{RIGHT}WARNING:BIASED LOW~{LEFT}	
88	{IF LEFT=22}WLe~{RIGHT}WARNING:BIASED LOW OR ERRATIC~{LEFT}	
89	{IF LEFT=23}WHi~{RIGHT}WARNING:BIASED HIGH, POSSIBLE INTERCEPT PROBLEM~{LEFT}	
90	{IF LEFT=24}WHI~{RIGHT}WARNING:BIASED HIGH, PROBABLE INTERCEPT PROBLEM~{LEFT}	
91	{IF LEFT=25}WHs~{RIGHT}WARNING:BIASED HIGH, POSSIBLE SLOPE PROBLEM~{LEFT}	
92	{IF LEFT=26}WHS~{RIGHT}WARNING:BIASED HIGH, PROBABLE SLOPE PROBLEM~{LEFT}	
93	{IF LEFT=27}WH~{RIGHT}WARNING:BIASED HIGH~{LEFT}	
94	{IF LEFT=28}WHe~{RIGHT}WARNING:BIASED HIGH OR ERRATIC~{LEFT}	
95	{IF LEFT=29}WOC~{RIGHT}WARNING:ONE RESULT ERRATIC~{LEFT}	
96	{IF LEFT=30}WER~{RIGHT}WARNING:BOTH RESULTS ERRATIC~{LEFT}	
97	/RNCLEFT~{DOWN}~	
98	{DOWN}	
100	/wchn3..av3~	
101	{goto}be3~@if(av3>1,i3,"")~{right}+N3~{right}+O3~	
102	/cbe3..bg3~be3..bg43~	
103	{goto}bg44~100~{down}+100~{right}0~{up}200~	
104	{goto}bg46~0~{right 2}100~	
105	{goto}bg47~200~{right 2}100~	
106	{goto}bg48~0~{right 3}0~	
107	{goto}bg49~200~{right 3}200~	
108	{goto}bg50~(N59*100)~{right 4}0~	
109	{goto}bg51~+100+100-(100*n59)~{right 4}~+200~	
110	{goto}bg52~+100~{right 5}+100+(2*j51)~	
111	{goto}bg53~+100~{right 5}+100+(3*j51)~	
112	/grgtxxbg3..bg53~abf3..bf53~bbh3..bh53~cbi3..bi53~dbj3..bj53~ebk3..bk53 ~fbl3..bl53~	

CODE-REL(cont.)

LINE	B	G
113	ocfglasfsqsymu200~L0~qsxmu200~L0~q	
114	dabe3..be53~aq	
115	tfMOE INTERLABORATORY STUDY ~TS LOW SAMPLE VS HIGH SAMPLE ~TXHIGH SAMPLE (% OF MEDIAN)~TYLOW SAMPLE (% OF MEDIAN)~QV	